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1 A KNEE BRACE ALTERS PATELLA POSITION IN PATELLOFEMORAL  
2 OSTEOARTHRITIS: A STUDY USING WEIGHT BEARING MAGNETIC  
3 RESONANCE IMAGING.

4  
5 ABSTRACT

6 Objective: To assess using weight bearing MRIs, whether a patellar brace altered  
7 patellar position and alignment in patellofemoral joint (PFJ) osteoarthritis (OA).

8  
9 Design: Subjects age 40-70 years old with symptomatic and a radiographic K-L  
10 evidence of PFJOA. Weight bearing knee MRIs with and without a patellar brace  
11 were obtained using an upright open 0.25 Tesla scanner (G-Scan, Easote Biomedica,  
12 Italy).

13 Five aspects of patellar position were measured: mediolateral alignment by the bisect  
14 offset index, angulation by patellar tilt, patellar height by patellar height ratio (patellar  
15 length / patellar tendon length), lateral patellofemoral contact area and finally a  
16 measurement of patellofemoral bony separation of the lateral patellar facet and the  
17 adjacent surface on the femoral trochlea (Figure 1).

18  
19 Results: Thirty participants were recruited (mean age 57 SD 27.8; BMI 27.8 SD 4.2);  
20 17 were females. Four patients had non-usable data. Main analysis used paired t tests  
21 comparing within subject patellar position with and without brace.

22 For bisect offset index, patellar tilt and patellar height ratio there were no significant  
23 differences between the brace and no brace conditions. However, the brace increased  
24 lateral facet contact area ( $p = .04$ ) and decreased lateral patellofemoral separation ( $p =$   
25  $.03$ ).

26 Conclusion: A patellar brace alters patellar position and increases contact area  
27 between the patella and femoral trochlea. These changes would lower contact stress  
28 at the PFJ. Such changes in patella position in weight bearing provide a possible  
29 biomechanical explanation for the success of the PFJ brace in clinical trials on  
30 PFJOA.

31

## 32 INTRODUCTION.

33 Patellofemoral (PF) osteoarthritis (OA), a common subtype of knee OA, is a major  
34 cause of pain with stair climbing, arising from a chair and activities involving  
35 kneeling or squatting. It is associated with pain, stiffness and functional limitation<sup>3, 5</sup>.  
36 Guidelines for the non-surgical management of generalised knee OA found 'fair'  
37 quality of evidence for the use of knee braces and knee sleeves <sup>21 9</sup>. Treatment of  
38 PFOA is similarly limited but one potential treatment is a patellar sleeve device.  
39 Evidence for its clinical efficacy is provided by two clinical trials in PFOA<sup>1, 8</sup>. These  
40 trials had positive effects on pain and structure from wearing a patellar sleeve brace  
41 compared to no brace<sup>1</sup> and on pain with or without the patellar retaining strap.<sup>8</sup>  
42 One of the proposed reasons for this clinical success is that the patellar brace may,  
43 during weight bearing activities, change patellar alignment and alter patellar tracking  
44 relative to the trochlear groove both of which are considered major contributions to  
45 the pathomechanics of PF pain. Whilst a brace's effects on the biomechanics of the  
46 PF joint are still not well understood, there is evidence from studies in non-arthritis  
47 PF pain that it may correct malalignment<sup>17</sup> and increase contact area of the PF joint<sup>18</sup>.  
48 This distribution of forces over a greater area could decrease the contact stresses.  
49 Several authors agree that magnetic resonance imaging (MRI), with its capability of  
50 viewing the patellar position in various planes, is more useful and informative than

51 plain radiography<sup>6, 10, 12</sup>. MRIs also have the advantage of using non-ionising radiation  
52 enabling repeated imaging, as in the present study, with and without a brace. Weight  
53 bearing MRIs may give a more valid view of PF congruence and position under  
54 natural loads exerted by body mass. Patellofemoral position is usually assessed  
55 clinically through palpation of the patella through a range of motion or by observing  
56 the motion of the skin over the patella. This assessment is commonly performed in a  
57 seated, unloaded posture that does not reflect joint movement during functional,  
58 weight bearing tasks.

59 To date, one study has used weight bearing MRIs to assess braces on non-arthritic,  
60 symptomatic PF pain<sup>4</sup>. To our knowledge there have been none assessing PFOA,  
61 although McWalter et al<sup>11</sup> assessed a knee sleeve in PFOA with *simulated* weight  
62 bearing MRIs by applying 15% of body weight of axial load through the patient's  
63 foot.

64 Since PFOA is likely to affect either medial or lateral patellar compartments<sup>7</sup>, the  
65 effects of braces on patellar position might have a bearing on treatment choices and  
66 brace design. Consequently, the weight bearing MRI may give a more realistic view  
67 of PF congruence and be a more appropriate technique when assessing patella  
68 position.

69

## 70 Purpose

71 The purpose of this study on PFOA was to use weight bearing MRIs to assess whether a  
72 sleeve brace altered patellar position. The hypothesis was that there would be differences in  
73 measures of PF position after the application of a patellar brace compared to no brace.

74

75

## 76 METHODS

77 The study was approved by the XXX Local Research Ethics Committee (Ethics number  
78 09/H1012/35). It was performed at the XXXX and at the University XXXX

79

### 80 Subjects

81 We recruited a subset of subjects age 40-70 years who had been enrolled in a previous  
82 randomized trial of patellar brace treatment for people with PFOA<sup>2</sup>. They had a K-L  
83 score grade 2 or 3 in the PF compartment which was greater than K-L score for the  
84 tibiofemoral compartments (this score required at least probable narrowing of the PF  
85 joint on X-ray and definite osteophytes in the PF compartment). Those who did not  
86 have plain radiographs were assessed for PFOA by either MRIs or arthroscopy, for  
87 which we required typical changes of OA with at least cartilage loss present in the PF  
88 joint. Subjects were also assessed by an experience clinician for PF joint symptoms  
89 such as pain reproduced with stair climbing, kneeling, prolonged sitting or squatting  
90 or if they had lateral or medial patellar facet tenderness on palpation or a positive  
91 patellar compression test. Pain must have been present daily for the previous 3 months  
92 and the pain had to be sufficiently severe for a nominated aggravating activity to score  
93 of 40 or above on a 0-100mm visual analogue scale (VAS<sub>NA</sub>). The VAS<sub>NA</sub> has been  
94 found to be at least as sensitive, and in some cases more sensitive to change than the  
95 KOOS or WOMAC questionnaires<sup>13, 14</sup>. Typically, subjects' nominated aggravating  
96 activities were stair climbing, kneeling, prolonged sitting or squatting.

97

### 98 Exclusion criteria

99 Participants were excluded if they had a previous patellar fracture or patellar  
100 realignment surgery, if the predominant symptoms emanated clinically from the

tibiofemoral joint, from meniscal or ligament injury, if they had rheumatoid arthritis or other forms of inflammatory arthritis or if they had an intra-articular steroid injection into the painful knee in the previous month. For the purposes of the MRI, patients were excluded if they had a cochlear implant, metal objects in the body including a joint prosthesis, a cardiac or neural pacemaker, a hydrocephalus shunt, an intrauterine contraceptive device or coil, if they had kidney dysfunction or were undergoing renal dialysis.

#### MRI procedures

Participants had MRIs of their knee joint using an upright open 0.25 Tesla scanner (G-Scan, Easote Biomedica, Italy). Participants first remained supine for approximately 5 mins to enable the recovery of viscoelastic structures in the knee, as the participant had been weight-bearing prior to entering the scanner. Following this rest period, an initial positioning scan (scout) was performed followed by axial and sagittal plane scans. Scans had a TR range of 690 - 830ms and TE range of 14-28ms with a slice thickness of around 4mm and a gap between slices of 0.4mm. The bed of the MR scanner was then be tilted into the upright position 4 degrees inclined from the vertical to allow weight-bearing. Foot position was controlled by aligning the great toe with a piece of tape on the platform. The scan time for each sequence was 2:43 mins, with 1 acquisition. Subjects were randomised to the order of brace or no brace by sealed opaque envelopes under the supervision of the study statistician.

Images were viewed off line.

#### Study Intervention

The brace intervention consisted of a Bioskin Patellar Tracking Q Brace (Ossur UK, Stockport, England) (figure 1).

#### Patellar Alignment Measurements

Medical imaging software Clear Canvas Workstation (Version 7.0.0.) was used. All images were anonymised so that examiners were blinded to the patient identification and group conditions (brace or no brace).

Five measurements of patellofemoral alignment and congruence were taken.

Bisect offset index assessed medio-lateral patellar displacement relative to the femur

The technique was initially described by Stanford et al<sup>20</sup> and used by Powers et al<sup>16</sup>.

A line was drawn connecting the posterior femoral condyles on the slice in which the posterior condyles were most obvious and a perpendicular line was projected up

through the deepest point (apex) of the trochlea. Then another slice was found on

which the patellar width was clearest and on which a line could be drawn to measure

the width. Finally, these two slices were superimposed allowing us to project the line

anteriorly from the bisection of the posterior condylar line through the second line on

the patella<sup>16</sup>. To determine the patellar displacement by the bisect offset, the extent of

the patella lateral or medial to the perpendicular midline was expressed as a

percentage of the total patellar width. (Figure 2).

Medio-lateral patellar tilt angle was measured as the angle formed by the lines joining

the maximum width of the patella and the line joining the posterior femoral condyles

<sup>15, 16</sup> (Figure 3).

Lateral patellofemoral joint contact area was defined as areas of patella and femur

approximation in which no distinct separation could be found between the cartilage

borders of the two lateral joint surfaces (Figure 4). A line of contact was drawn

150 between the patella and the femur<sup>17</sup>. The contact area for each slice was measured and  
 151 multiplied by the length of the contact line with the slice thickness (0.4mm). Each  
 152 sequential image was summed to obtain the total lateral contact area  $\Sigma (CL \times$   
 153  $(SL \times SG))$  (CL = contact length; SL = slice length; SG = slice gap)  $\times (slice\ length +$   
 154  $slice\ gap)$ . Because cartilage was relatively bright on fat suppressed fast spoiled  
 155 gradient echo images, we used the operation definition of contact area as white on  
 156 white<sup>17</sup>. The determination of non-contact was made when a line of separation could  
 157 be observed between the articular surfaces of the patella and trochlear groove.  
 158 The level of agreement between the MRI and pressure sensitive film techniques in  
 159 cadaver specimens was for ICC 0.91 and for CV 13%. When averaged across all  
 160 specimens, the contact area obtained through MRI was 2.94 (SD 1.01 cm<sup>2</sup>) while  
 161 the contact area obtained using the pressure sensitive film technique was 3.05  
 162 (0.95 cm<sup>2</sup>). The average individual specimen difference between the two methods  
 163 was 10.9%.  
 164 The Insall-Salvati ratio was measured on the sagittal views by a ratio between patella  
 165 tendon length relative to the superior-inferior length of the patella (patellar length /  
 166 patellar tendon length)<sup>19</sup>. (Figure 5).  
 167 Patellofemoral distance (the distance between the patella and the femur) was  
 168 measured to assess if the brace reduced the distance between the opposing surfaces of  
 169 the patella and the femur, specifically the lateral patellar facet and the adjacent surface  
 170 on the lateral femoral trochlea. First, the area between patella and femur was  
 171 determined by drawing a trapezoid on an axial slice where patellofemoral distance  
 172 was greatest. The average distance between the patella and femur was measured by  
 173 dividing the area (automatically calculated by the Clear Canvas program) by the  
 174 longest side of the trapezoid (Figure 6).



## Reliability

Inter rater reliability for the MRI measurements was assessed between two assessors using a 2 way random model for absolute agreement inter-class correlation coefficient ( $ICC_{2,1}$ ). The results were for bisect offset index  $ICC_{2,1}$  0.97 (95%CI 0.96, 0.98) SEM 2.6, for patellar tilt angle  $ICC_{2,1}$  0.96 (95%CI 0.94, 0.97) SEM 1.43°, for lateral patellofemoral joint contact area  $ICC_{2,1}$  0.73 (95%CI 0.53, 0.85), SEM 3.1cm<sup>2</sup>, for the Insall-Salvati ratio  $ICC_{2,1}$  0.95, (95%CI 0.80, 0.98) SEM 0.031, and for patellofemoral distance  $ICC_{2,1}$  0.84, (95% CI 0.48,0.97), SEM 0.32cm.

## Analysis

Data were visually analysed with histograms, Q-Q plots and Kolmogorov-Smirnov tests which confirmed normality of distribution. The main within subjects analysis used paired t tests comparing patellofemoral alignment and congruence with and without a brace. Statistical significance was set at  $p \leq 0.05$ .

## RESULTS

Thirty subjects with PFOA were recruited (mean age 57, SD 7.8years, BMI mean 27.8, SD 4.2); 17 were females (56%). Five subjects had their PFOA assessed by MRIs or arthroscopy. Four patients had non-usable MRI data because of missing data on some parameters or because of technical problems such as movement artefact. Therefore 26 patients' data were analysed. There were no adverse events. For bisect offset index, patellar tilt and patellar height ratio there were no significant differences between the brace and no brace conditions. However, the brace significantly increased lateral facet contact area (0.94cm<sup>2</sup>, 95% CI 0.07, 1.8,  $p = .04$ ) and decreased lateral patellofemoral distance (-0.06cm 95% CI -0.12, -0.01,  $p = .03$ ) (Table 1).

## DISCUSSION

This is the first study using weight bearing MRIs on subjects with symptomatic PFOA to evaluate the effects of bracing on the PF joint. It found that the brace significantly increased the lateral contact area of the PF joint and decreased PF joint lateral distance. The other measures of PF joint position (bisect offset index, patellar tilt and patellar height ratio) were not altered significantly. MRIs are more useful and informative than plain radiography by viewing the patellar position in various planes<sup>6, 10, 12</sup>. MRIs also have the advantage of using non-ionising radiation enabling repeated imaging, as in the present study, with and without a brace. Using a scanner with the capability of providing standing weight bearing images adds to its usefulness. Comparison with previous research is compromised by the few weight bearing studies available, all of which were only done on non-arthritic PF pain. Draper et al.<sup>4</sup> found a patellar sleeve brace in females with non-arthritic PF pain produced non-significant reductions in weight bearing patellar tilt ( $0^0$ ) and bisect offset (4%) at full knee extension. Similarly, we did not find any significant differences in full knee extension between our patellar brace and no brace in bisect offset (1.39%, 95% CI -2.3, 5.1) and patellar tilt ( $-0.25^0$ , 95% CI -1.61, 1.1). The reasons for different values recorded are likely due to us assessing subjects with symptomatic PFOA and differences in the PF brace design suggesting that commercially available braces may have different biomechanical effects. McWalter et al<sup>11</sup> is the only comparable study looking at the same patellofemoral brace in the same knee condition, but differed from ours by using knee flexion up to  $50^0$  and lying subjects in supine with a simulated body weight load of 15%. They found the brace significantly altered patellar rotations and translations compared to no brace but questioned its clinical significance because no reduction in pain was observed in their parent trial<sup>8</sup>, which compared the brace with a modified

brace without a T-strap. The clinical significance of our findings for the parameters of lateral contact area and lateral patellofemoral distance may also be questioned, even though a clinically significant reduction in pain *was* observed in our parent trial which compared the brace to no a brace control<sup>2</sup>. As a result of our findings, we join with Draper et al. <sup>4</sup> in asking whether the small changes observed with a brace are sufficient to alter PF lateral contact area and lateral patellofemoral distance by a clinically meaningful amount. The small increases we recorded in these parameters concur with the work by Powers et al. <sup>17</sup> to explain the possible mechanism for the decrease in PF pain. They found, albeit in non-arthritic PF pain, that compared to no brace at full knee extension a PF brace had its greatest effect on lateral patellar facet contact area, had clinically small but statistically significant effects on the bisect offset index, but no effect on patellar tilt. They proposed the concept that the increased contact area would result in a decrease in joint area stress. Our PFOA subjects might have also benefitted from decreased joint area stress. Additionally, they may have benefitted from a sense of stability and confidence created wearing the brace. Although this was not objectively assessed in this study, patients in the parent trial<sup>2</sup> reported that their knee felt more stable and secure from brace wearing. All our subjects had an improvement in their VAS for a nominated activity and their KOOS after wearing the patellar brace as part of a randomised trial<sup>2</sup>. This trial, in conjunction with the present study shows that a PF brace has both symptomatic and biomechanical benefits for those with symptomatic PFOA.

## LIMITATIONS

The limitations of this study are that the MRIs were taken only in a single WB position, with no variability of knee flexion. The 0.2T field strength for the weight

bearing MRI scanner used in this study has implications for the contrast resolution obtainable in an acceptable time. Participants were not blinded to the brace wearing condition. Additionally, as this was a subgroup from a previous trial, there was no further subgroup analysis of patients based on the severity or location of the PFOA.

## CONCLUSION

A patellar brace significantly increases PFJ lateral contact area and decreases PFJ lateral distance. This likely lowers contact stress at the PFJ. Such changes in PFJ position in weight bearing provide a possible biomechanical explanation for the success of the PF brace in clinical trials on PFOA.

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Drafting of the article: Callaghan, Felson, Guney, Bailey, Hodgson.

Final Approval: Callaghan, Felson, Hodgson, Guney, Reeves.

272 Provision of study facilities or patients: Callaghan, Felson, Reeves, Maganaris,  
273 Doslikova.  
274 Statistical expertise: Felson, Callaghan, Hodgson.  
275 Obtaining of funding: Felson, Reeves, Maganaris  
276 Collection and assembly of data: Callaghan, Doslikova, Reeves, Maganaris, Bailey,  
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278

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287

288 **Competing interests**

289 None of the authors have competing interests related to this work.

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Figure 1 The Bioskin Patellar Tracking Q brace.





Figure 2

Mediolateral displacement (Bisect Offset index)

Figure 2 a: ideal image to measure patellar width.

Figure 2 b: ideal image to view posterior condyles and trochlea

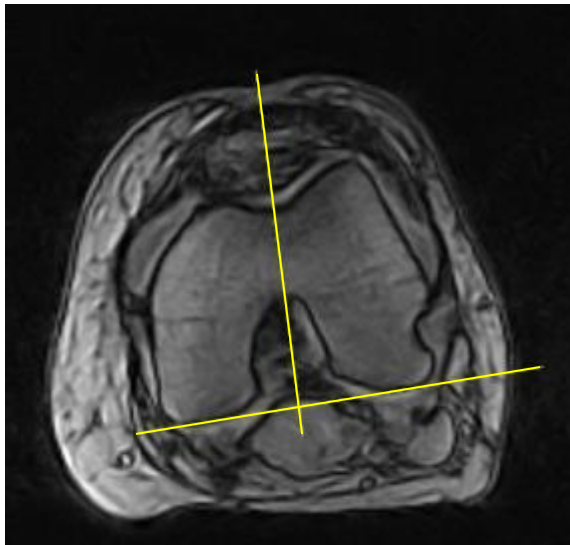
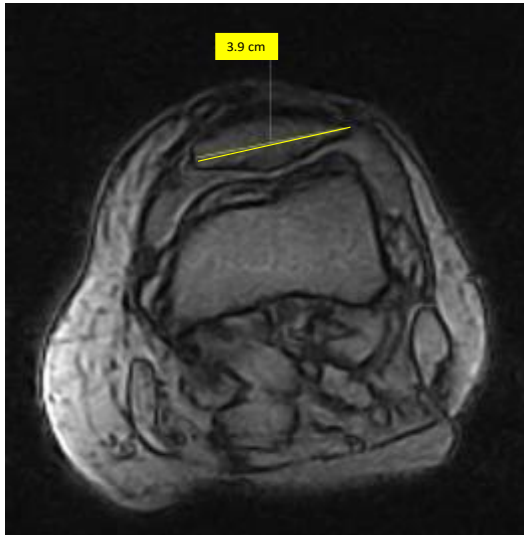


Figure 3  
Patellar Tilt Angle

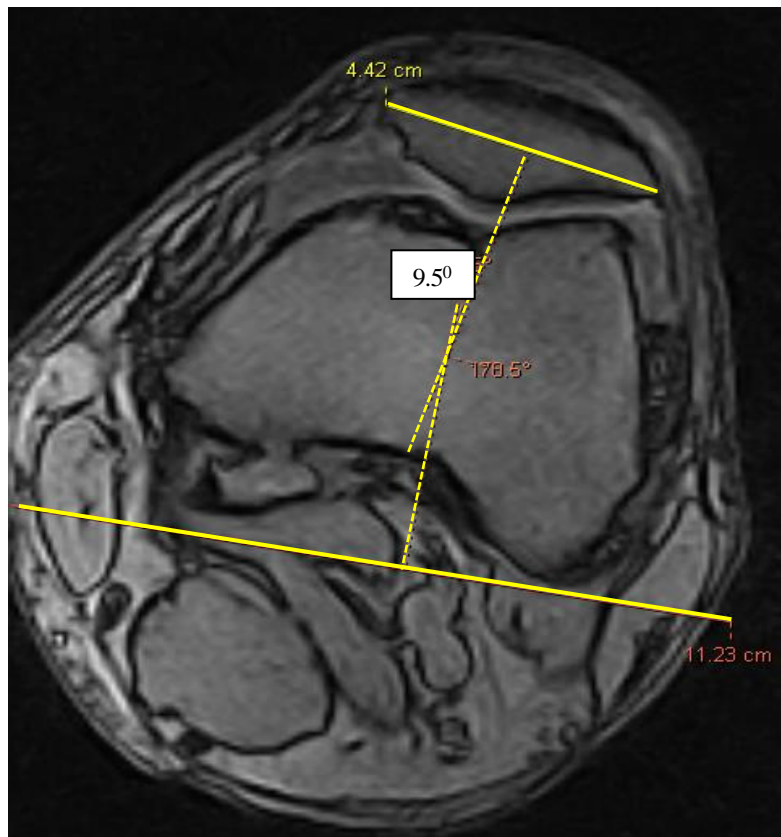


Figure 4  
Lateral Patellofemoral Contact Area

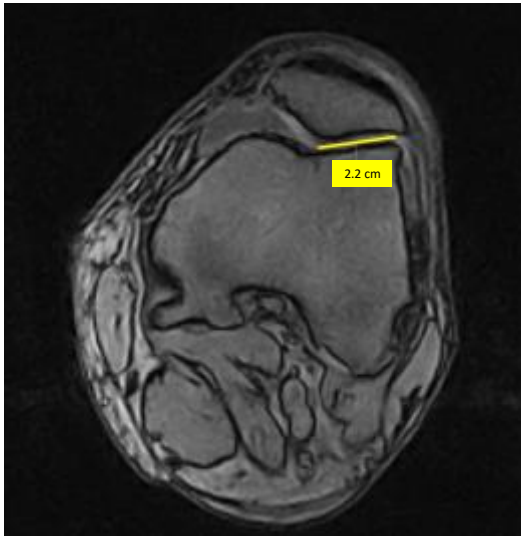


Figure 5  
Insall-Salvati Ratio Patellar bone length / Patella tendon length



Figure 6  
Patellofemoral Distance  
Area of Trapezoid  $a+b/2 \times h$  / length of lateral PF contact

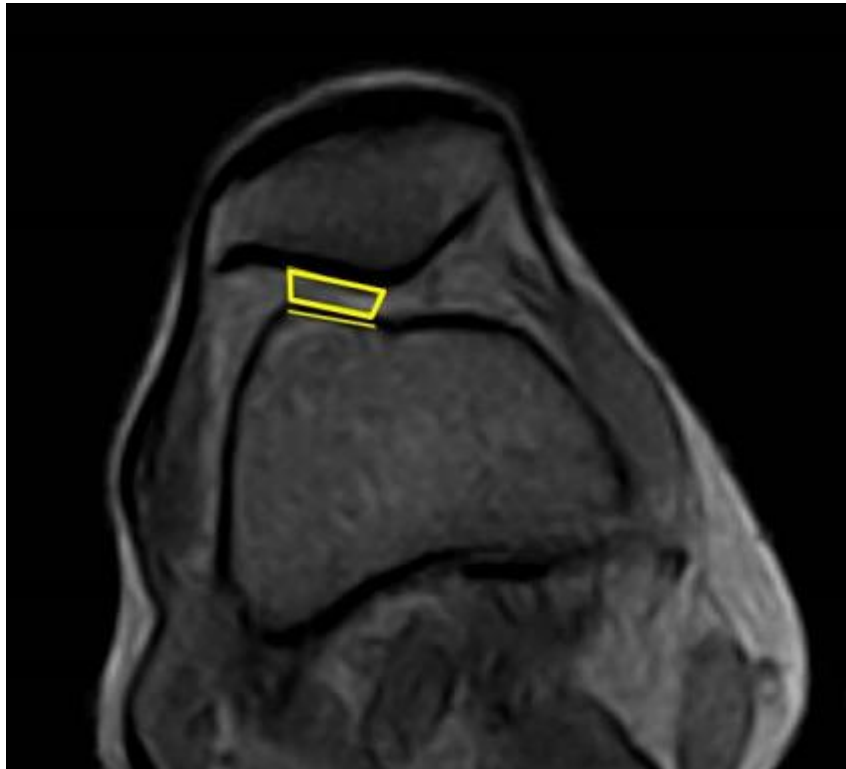


Table 1. Patients' Demographics

	Mean $\pm$ SD
Age (year)	57.17 $\pm$ 8.1
BMI (kg/m <sup>2</sup> )	27.76 $\pm$ 4.39
Gender (female/male)	15/13
K-L PFJ Score 3/2/1	12/6/1
K-L TFJ Score 3/2/1	12/5/2

Legend:

BMI = Body Mass Index  
K-L = Kellgren Lawrence  
PFJ = Patellofemoral Joint

Table 2 Results:

	Patellar tilt Mean (SD) deg N = 27	Bisect offset Index Mean (SD)% N = 27	Patellar length/ tendon length ratio Mean SD N = 27	Patellofemoral Lateral Contact area cm <sup>2</sup> Mean SD N = 26	Patellofemoral Distance cm Mean SD N =26
Brace	8.63 (6.6)	72.4 (19.1)	1.0 (0.17)	2.73 (2.4)	0.27 (0.12)
No Brace	8.39 (4.9)	73.8 (18.4)	0.96 (0.13)	1.79 (2.2)	0.33 (0.13)
Mean difference	-0.25 (95% CI -1.61, 1.1)	1.39 (95% CI -2.3, 5.1)	0.05 (95% CI -0.01, 0.11)	0.94 (95% CI 0.07, 1.81)	-0.06 (95% CI -0.12, -0.01)
P value	0.71	0.44	0.09	0.04	0.03